Short Communication

Relative Susceptibility of Potato Varieties to *Streptomyces scabiei* and *S. acidiscabies*

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ABSTRACT

In 2000 and 2004, 19 potato varieties were grown in separate plots inoculated with the scab pathogens *Streptomyces scabiei* and *S. acidiscabies*. Reaction of the varieties to these two species were highly correlated in both years, with no host variety-pathogen species interaction. These results are consistent with the central role of the bacterial toxin thaxtomin in scab development, and indicate that this and other mechanisms involved in pathogen infection and establishment are not expressed differentially with regard to variety. Likewise, there is no apparent differential response of the pathogens to those host factors determining the degrees of resistance and symptoms expressed in different varieties.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is susceptible to raised or pitted scab incited by various *Streptomyces* species (Loria et al. 1997). This disease is referred to as "common scab" in its broadest sense, although the term is often restricted to acid-intolerant or raised lesion types in some potato-growing regions. Pathogens previously placed in the species *S. scabiei* (Lambert and Loria 1989a) include a range of phenotypically similar individuals whose genetic diversity substantially exceeds accepted within-species norms of DNA homology (Bouchek-Mechiche et al. 2000; Bukhalid et al. 2002; Healy and Lambert 1991; Paradis et al. 1994). Additional species causing raised or pitted scab have been described and include, to date, *S. europaeiscabiei* (a genomospecies split from *S. scabiei* on the basis of DNA homology), *S. stelliscabiei* (Bouchek-Mechiche et al. 2000); *S. acidiscabies* (Lambert and Loria 1989b); *S. turgidiscabies* (Miyajima et al. 1998); *S. caviscabies* (Goyer et al. 1996); *S. luridiscabiei*, *S. puniscabiei* and *S. niveiscabiei* (Park et al. 2003).

Pathogenicity in these species is dependent on the production of thaxtomin (Lawrence et al. 1990), a toxin affecting cellulose deposition and cell wall development (Fry and Loria 2002; Loria et al. 2003; Scheible et al. 2003). Genes for this and other virulence functions have proliferated as a unit among these *Streptomyces* species by horizontal transfer (Bukhalid et al. 2002; Kers et al. 2005; Loria et al. 2003). Consequently, the pathogen population is becoming genetically and ecologically more diverse.

This is troubling, as scab has historically been managed by exploiting the ecological limitations *S. scabiei* faces at extremes of soil pH and in wetter soils. Of the scab species differing in ecological adaptations that might interact more directly with potato variety, *S. acidiscabies* appears unique. Although it shares the same host range as *S. scabiei* (Lambert 1991), *S. acidiscabies* is primarily seedborne rather than soilborne (Bonde and McIntyre 1968; Manzer et al. 1977). In contrast to *S. scabiei*, *S. acidiscabies* may be suppressed by soil-applied insecticide/nematicides (Manzer et al. 1991), suggesting that soil microfauna play an important role in its infection and or dissemination (Manzer et al. 1984).

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Potato varieties vary considerably in response to scab (Goth et al. 1993), with a significant variety X environment interaction (Haynes et al. 1997). Because thaxtomin production is the common and primary pathogenicity mechanism in raised and pitted scab, one might presume that relative varietal response to different scab pathogen species is nearly identical. This would occur if there were no species x variety interactions in toxin production or differential responses to host defenses. Reeves (unpublished) evaluated scab caused by *S. scabiei* and *S. acidiscabies* separately and found highly correlated varietal responses in 1984 (r = 0.679, 20 potato lines) and 1986 (r = 0.995, 6 lines) but not 1985 (r = 0.134, 14 lines with one outlier). This study was conducted to verify that a variety's susceptibility to the two species is the same relative to other potato varieties and that separate disease evaluations are not required.

METHODS

In 2000, five-hill plots replicated four times were planted with 1600 lb 10-10-10 fertilizer. Scab inocula for *S. scabiei* and for *S. acidiscabies* were prepared from scabby 'Katahdin' potato tubers by peeling scab lesions and grinding them in distilled water. Freshly cut seedpieces of 20 varieties were dipped into the respective inocula just prior to planting, and covered by hand. Harvested tubers were stored, washed and scored for lesion type (LI), where 0 = none, 1 = superficial lesions < 10 mm in diameter, 2 = superficial lesions > 10 mm, 3 = raised lesions < 10 mm, 4 = raised lesions > 10 mm, 5 = pitted lesions) and % surface area (SAI) affected (Goth et al. 1993). In 2004, the type strains of *S. scabiei* (ATCC 49173) and *S. acidiscabies* (ATCC 49003) were grown in trypticase soy broth in 500-1000 mL batches in shake cultures. As growth became dense, the cultures were poured off into fine horticultural vermiculite. Cultures were added until the point at which the vermiculite was still sufficiently dry to sprinkle easily. Rows were inoculated in-furrow and before hilling at the rate of 250 mL vermiculite per 5 hills per inoculation. Nineteen of the 20 varieties from 2000 were planted in five-hill, 1.5-m plots separated by 1.5-m gaps and replicated five times in randomized complete blocks. Separate fields were used for the two pathogens. The field used for *S. acidiscabies* had no history of scab. In the field used for *S. scabiei*, scab was moderately severe in the previous potato crop. Tubers were stored and subsequently evaluated by weight into no (0%-1% surface coverage), light (1%-10% coverage) or heavy (>10% coverage) categories. The 2004 scab index was calculated as ($weight_{light}$ + 2 [$weight_{heavy}$])/ $weight_{total}$ for each plot. Data from the two years were analyzed by mean separation with Tukey's *hsd*, and correlations (Pearson product moment) between the various pathogen species/year/indices were determined. In 2004, data was subjected to analysis of variance to detect any pathogen species – variety interaction.

RESULTS AND DISCUSSION

Scab expression was sufficient in all trials to adequately differentiate varietal responses (Table 1). In 2000, lesion index (LI) and surface area index (SAI) were highly correlated for each pathogen species (Table 2). Although the 2004 index was based on surface area affected, it was more highly correlated with LI in 2000 than with SAI. Disease severity was moderately higher for *S. scabiei* in 2000 (Table 1), but much heavier for *S. acidiscabies* in 2004. Correspondingly, the greatest differentiation of varieties was obtained with *S. acidiscabies* in 2004. Varietal indices were very highly correlated between scab species within years, within species between years, and between species and years (Table 2). Seventy-seven percent of all variance was explained by variety in 2004, 77% for the LI in 2000 and 59% for the SAI in 2000. Equivalent correlation analyses of varietal rankings (Table 1) produced similar results, and are not shown. Correlations between 2004 data and both LI and SAI in 2000 averaged slightly higher between pathogen species (.768 and .626 respectively) than the equivalent correlations within pathogen species (.747 and .580 respectively), indicating a lack of pathogen variety interaction. Likewise, analysis of the 2004 data indicated no differential effect of the two species on varieties. Variability in varietal ranking was significantly greater ($P < 0.025$) between years than between pathogen species (by t-test).

Reaction to common scab is routinely determined during potato variety development in field plots naturally or deliberately infested with pathogenic *Streptomyces*. Screening on plantlet-derived minitubers is also useful, but more so for qualitative assessments of pathogen virulence than for routine quantitative assessments of resistance. Field evaluations are used to categorize scab severity relative to standard varieties or to select for or screen out potato progeny with particularly good or poor scab resistance. Optimizing trials may require supplemental plot inoculation. Our results indicate that sepa-

TABLE 1—*Scab severity indices and relative severity ranking for 19 potato varieties inoculated with* S. scabiei *or* S. acidiscabies.

	2004				2000							
					lesion index (LI)				scab area index (SAI)			
	S. acidiscabies		*S. scabiei*		*S. acidiscabies*		*S. scabiei*		*S. acidiscabies*		*S. scabiei*	
Variety	rank	index	rank	index	rank	index	rank	index	rank	index	rank	index
AF1615-1	5	1.48 b-d[1]	8	0.18 ab	2	0.17 ab	4	0.28 a-c	2	0.17 ab	5	0.22 c-e
AF1753-16	17	1.91 gh	14	0.46 b-e	16	0.40 c-f	13	0.50 d-f	12	0.23 a-c	17	0.32 a-c
Andover	9	1.61 c-g	9	0.25 a-c	3	0.19 a-c	9	0.37 a-e	3	0.18 a-c	7	0.24 b-e
Atlantic	10	1.62 c-g	5	0.15 ab	5	0.21 a-d	5	0.31 a-d[1]	5	0.19 a-c	4	0.22 c-e
Chieftain	8	1.58 c-f	4	0.10 ab	11	0.27 a-e	11	0.42 b-e	11	0.22 a-c	10	0.28 a-e
D. R. Norland	4	1.36 a-c	6	0.16 ab	4	0.21 a-d	3	0.26 a-c	7	0.19 a-c	2	0.20 de
Kanona	13	1.85 f-h	13	0.43 b-e	19	0.50 f	19	0.64 f	19	0.29 a	19	0.35 a
Katahdin	12	1.83 e-h	12	0.43 b-e	14	0.35 b-f	15	0.52 d-f	14	0.24 a-c	9	0.28 a-e
Kennebec	14	1.86 f-h	19	0.79 e	15	0.37 b-f	12	0.47 c-f	16	0.26 a-c	16	0.29 a-d
Monona	7	1.55 b-e	7	0.17 ab	8	0.25 f	10	0.40 a-e	9	0.21 a-c	15	0.29 a-e
Norwis	15	1.86 f-h	15	0.54 c-e	17	0.41 d-f	17	0.53 d-f	18	0.29 a	12	0.28 a-e
Ontario	3	1.29 ab	3	0.09 ab	6	0.22 a-e	2	0.23 ab	13	0.24 a-c	11	0.28 a-e
Quoggy Joe	18	1.91 gh	17	0.58 c-e	12	0.29 d-f	14	0.52 d-f	10	0.21 a-c	13	0.28 a-e
Reba	6	1.53 b-e	10	0.35 a-d	9	0.25 a-e	7	0.35 a-d	4	0.18 a-c	6	0.23 c-e
R. Burbank	1	1.17 a	1	0.04 a	1	0.12 a	1	0.19 a	1	0.17 c	1	0.20 e
R. Norkotah	11	1.74 d-h	11	0.38 a-c	13	0.30 a-f	8	0.35 a-d	15	0.24 a-c	8	0.25 b-e
Shepody	16	1.87 f-h	15	0.54 c-e	18	0.44 ef	18	0.57 ef	17	0.28 ab	18	0.33 ab
Superior	2	1.17 a	2	0.56 a	7	0.25 a-e	6	0.33 a-d	8	0.20 a-c	3	0.22 de
Yukon Gold	19	1.94 h	18	0.67 de	10	0.26 a-e	16	0.52 d-f	6	0.19 a-c	14	0.29 a-e

[1]Means followed by the same letter do not differ at the 5% level of statistical significance.

TABLE 2—*Correlation*[1] *matrix of scab index values (LI = Lesion Index, SAI = Surface Area Index) for* S. scabiei *and* S. acidiscabies *in 2000 and 2004. Equivalent year/index comparisons of pathogen species are in bold.*

		2004	2000			
		S. scabiei	*S. acidiscabies*		*S. scabiei*	
			LI	SAI	LI	SAI
S. acidiscabies	2004	**.876**[1]	.730	.558	.875	.730
S. scabiei	2004		.661	.525	.763	.601
S. acidiscabies	LI 2000			.900	.879	.852
S. acidiscabies	SAI 2000				.693	.766
S. scabiei	LI 2000					.852

[1]r = 0.456 @ $P = 0.05$, r = 0.575 @ $P = 0.01$, r = 0.693 @ $P = 0.001$

rate evaluations are not needed for *S. scabiei* and *S. acidiscabies*, and that these species may be used interchangeably for scab evaluation. This also suggests that varietal responses to the other pathogenic *Streptomyces* species may be similar as well. While *S. acidiscabies* appears to occur infrequently in potato production, it has several potential advantages for disease screening. This species may be used over a wide soil pH range, it appears to be disseminated within the soil from discrete inoculation sites (DHL, unpublished), and it is not the long-term soil contaminant that *S. scabiei* might be. It appears that thaxtomin production and any other capabilities required for infection and pathogen establishment are not differentially expressed by these two species with regard to host variety. This does not take into account conceivable varietal differences affecting subsequent saprophytic survival and spore production by *S. acidiscabies* in scab lesions, factors of greater importance for this seedborne species.

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